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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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MILLING METHODS AND COSTS AT THE SPRING HILL CONCENTRATOR OF THE MONTANA MINES CORPORATION, HELENA, MONT.

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MILLING METHODS AND COSTS AT THE SPRING HILL CONCENTRATOR OF THE MONTANA MINES CORPORATION, HELENA, MONT.[1]

By L. A. Grant[2]

INTRODUCTION

This paper describing the concentrator practice of the Montana Mines Corporation at Helena, Mont., is one of a series of articles on milling methods and costs being prepared by the United States Bureau of Mines.

The Spring Hill mine and mill are located 4 miles south and west of Helena, Mont., near the head of Grizzly Gulch. The mine portal is on the east slope of the gulch, and the mill is directly opposite on the west slope. Grizzly Gulch is one of the two gulches which unite at the south end of Helena to form Last Chance Gulch, on which the main street of Helena is built.

BRIEF HISTORY OF CONCENTRATOR

The mill was built as a cyanide plant late in 1927, and it operated as such from February, 1928, until March, 1929. The ore did not respond to cyanide treatment, due to fouling of the solutions by antimony and arsenic, with a resultant loss of gold. In April, 1929, the mill was converted into a straight flotation treatment plant. Operation was resumed on May 1, 1929, and from that date Spring Hill ore has been concentrated by bulk flotation methods.

MINING METHODS AND DESCRIPTION OF ORE TREATED

The ore is broken in a quarry or glory hole and in a shrinkage stope in the mine, passed through chutes and ore passages to the main haulage level below, trammed in 2-ton capacity cars, and dumped directly into the coarse ore bin of the crushing plant. All of the ore delivered to the crusher bin is very dry.

The ore bodies occur disseminated through diorite rock along a diorite-limestone contact. The diorite, the principal gangue mineral, is very hard and tough, causing difficulties in both mining and crushing operations. It breaks into large irregular slabs, and these are broken further in the mine, just enough to permit loading of the ore into the 2-ton capacity cars.

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1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6411."

2 - One of the consulting engineers, U. S. Bureau of Mines, and Mill superintendent, Spring Hill Concentrator.

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The valuable metal content of Spring Hill ore is gold. Most of the gold is associated with pyrite, arsenopyrite, and bismuth, but an average of from 10 to 15 per cent of it occurs in the native condition and usually very finely divided.

Pyrrhotite, the most important sulphide in the ore as to volume, is barren of values and is a source of difficulty in the concentrating process, since it floats with the gold-bearing sulphides and dilutes the concentrates.

POWER SUPPLY

The Montana Power Co. supplies all the power used at the mine and mill at 10,000 volts. This voltage is stepped down to 2,200 or 400 volts at the transformer station, as all motors are either 2,200-volt or 400-volt, 3-phase, 60-cycle.

The Montana Power Co. delivers power for $0.0055 per kilowatt hour. The actual cost of power, however, to the Spring Hill property, is $0.008 per kilowatt hour, and this figure is used in all calculations.

PRESENT METHOD OF CONCENTRATING

The flow sheet of treatment is not complicated, consisting principally of crushing, grinding, floating, and dewatering.

Crushing

Figure 1 shows a plan of the crushing plant. The equipment of this plant consists of one 24 by 36 inch Traylor jaw crusher belted directly to a 75-horsepower slip-ring motor which drives it at a speed of 198 revolutions per minute; one 14 by 18 inch jaw crusher belted directly to a 75-horsepower straight induction motor which drives it at a speed of 260 revolutions per minute; and one 3-foot Symons fine cone crusher, belted directly to a 60-horsepower straight induction motor which drives it at a speed of 530 revolutions per minute. The tramming and the crushing of ore are done in two 8-hour shifts, the crushers operating about 12 hours per day.

The 24 by 36 inch crusher takes the ore as it is delivered to the ore bin from the mine, the ore being fed through chute gates. The grizzly, usually installed between the ore bin and the crusher, was omitted partly to restrict the crusher discharge and partly to enable large slabs to enter the crusher more readily. The crusher is set at 5 inches and delivers crushed product at the rate of 20 tons per hour directly onto an 18-inch cross conveyor belt. This conveyor belt carries the ore under a suspended magnet for the removal of drill bits and small pieces of tramp iron, and it then continues on for 55 feet, where it dumps the ore onto a self-cleaning bar grizzly. This grizzly is 3 1/2 feet long with 1-inch openings at the feed end and 1 1/2-inch openings at the discharge end. The construction of the grizzly is shown in Figure 1.

The oversize product of the grizzly falls into the mouth of a 14 by 18 inch jaw crusher set at 1 1/2 inches. The crushed product is delivered

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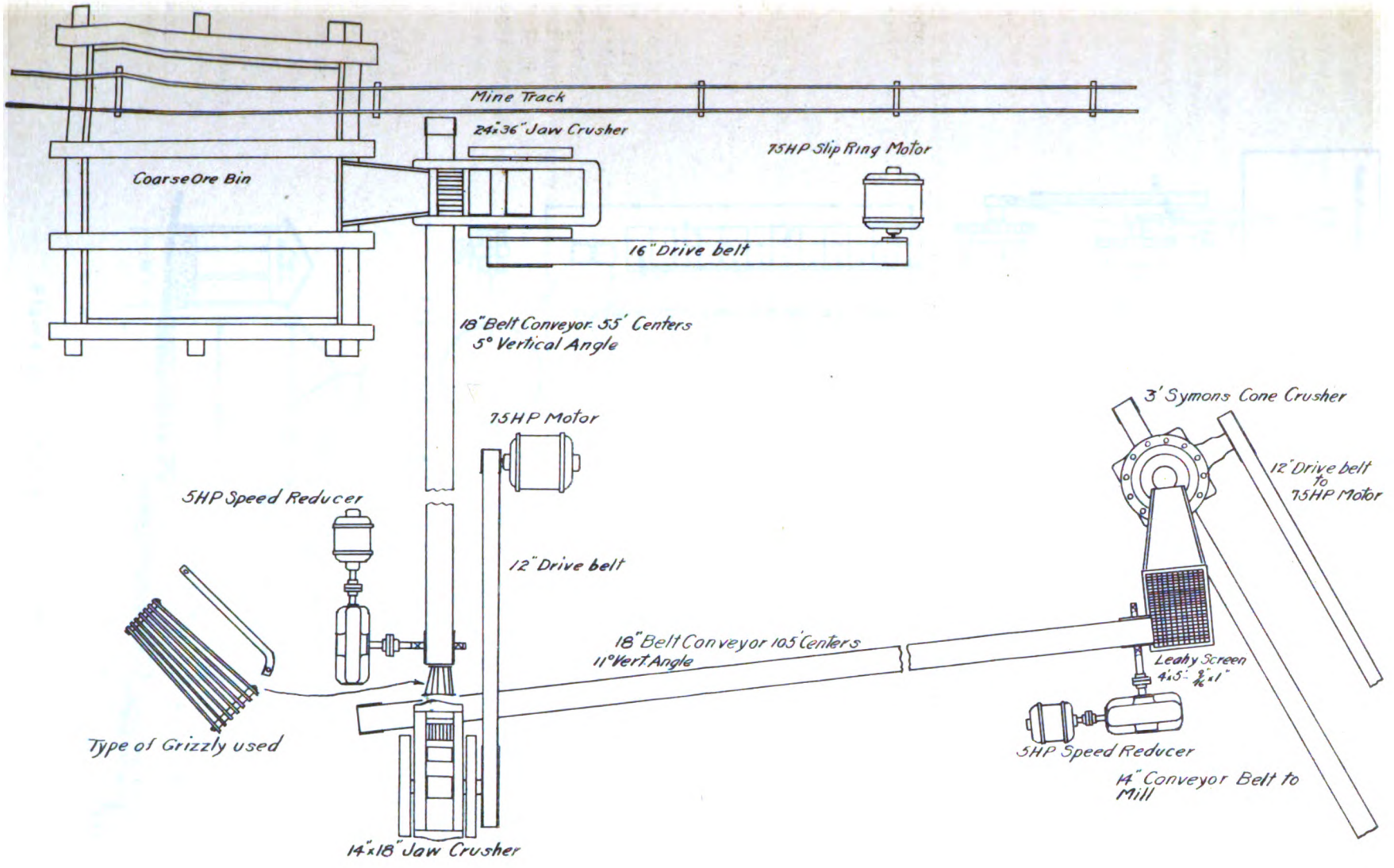

Figure 1.- Plan of crushing plant, Spring Hill mill

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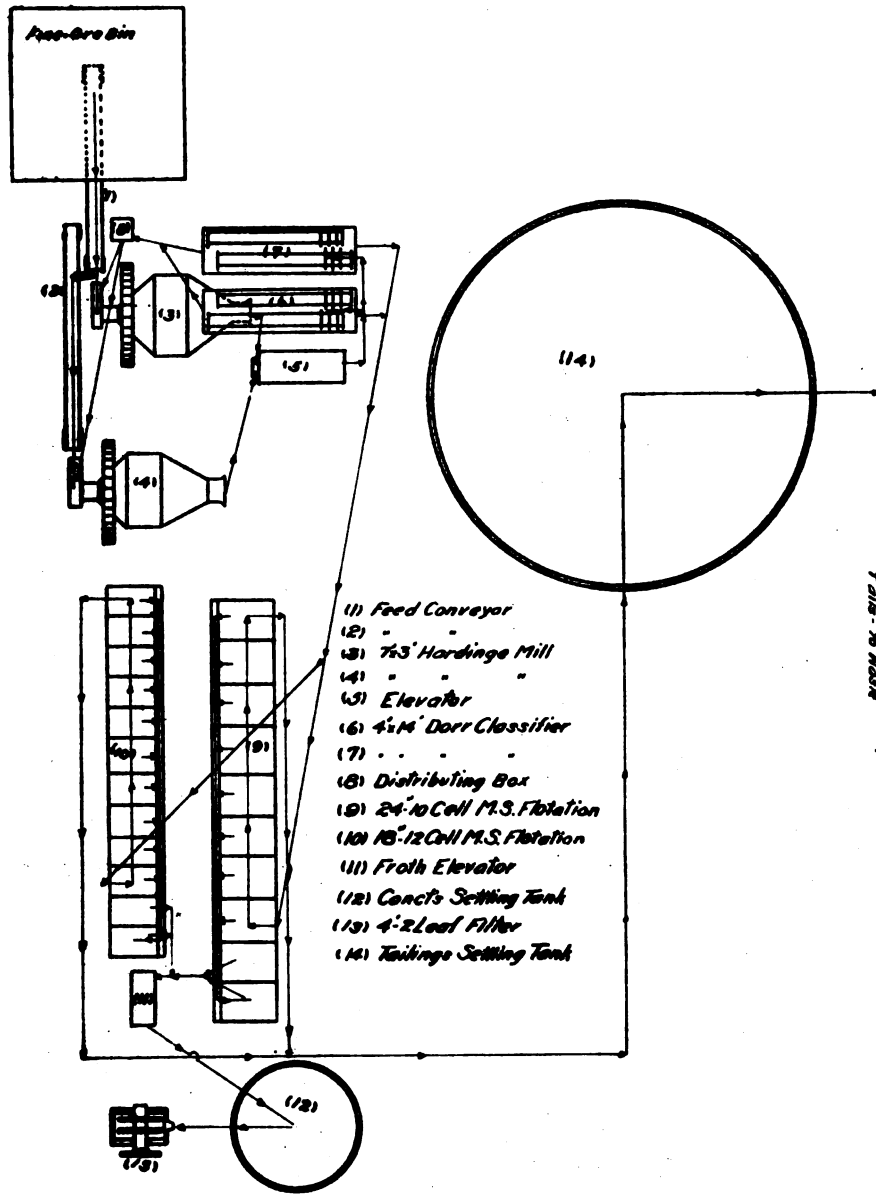

Figure 2.- Flow sheet of concentrator

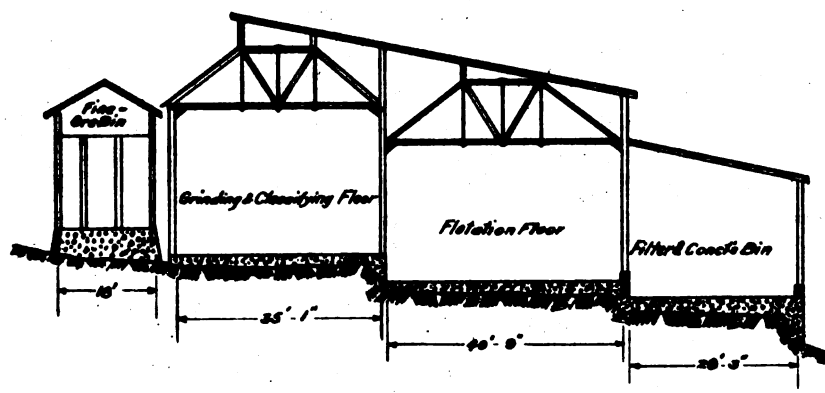

Figure 3.- Side elevation of mill building

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to an 18-inch cross conveyor belt which also receives the undersize of the grizzly, amounting to approximately 20 per cent of the grizzly feed. This conveyor belt carries the ore up an incline of 11° for a distance of 105 feet and dumps it on a 4 by 5 foot Leahy vibrating screen equipped with ton-cap-screen cloth having nine-sixteenths by 1 inch openings.

The oversize product of this screen falls directly into the mouth of a 3-foot Symons fine cone crusher, set at one-half inch. The cone crusher delivers the crushed product, containing material 6.7 per cent coarser than the Leahy screen openings, to a 16-inch belt conveyor which also receives the undersize of the Leahy screen, amounting to about 30 per cent of the screen feed. This conveyor delivers the crushing plant product to the concentrator storage bin. The 16-inch conveyor belt is 780 feet long and in two sections, the first of which is 350 feet long and the second 430 feet long.

All of the crushers are equipped with manganese steel liners. Figures on the life of the liners and the cost of liners per ton of ore crushed in the jaw crushers are not yet available, as the initial liner installations are still in service. The liners of the cone crusher are replaced about every nine months. The cost of these liners amounts to $0.0066 per ton of ore crushed.

The costs of power, labor, and miscellaneous expense for crushing and conveying are given in Table 1.

Table 1.--Crushing costs

	Per ton of ore crushed
Power	$ 0.049
Labor	.063
Supplies and repairs	.110
Total	$ 0.222

Concentrator

Figure 2 gives a flow sheet of ore treatment in the concentrator and Figure 3 shows a side elevation of the concentrator building.

Grinding

The concentrator storage bin has a capacity of 200 tons of ore. From the bottom of this bin the ore is delivered to two 7-foot by 36-inch Hardinge conical ball mills by 16-inch belt conveyors. Each ball mill is belted directly to a motor and each operates at a speed of 23 revolutions per minute. One ball mill is driven by a slip-ring 125-horsepower motor and starts without a clutch; the other has a straight induction 150-horsepower motor and is started with a clutch. Each ball mill grinds at the rate of 4.2 tons of new ore per hour. The ground products, consisting of five parts of circulating load and one part of new feed and containing 50 to 60

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per cent of solids, discharge into one elevator, which in turn discharges the products into a distributing box feeding two overhead 4 by 14 Dorr classifiers. The sand products of the classifiers go to a distributing box which feeds either or both ball mills. The overflow products of the classifiers go directly to the flotation cells.

White cast iron, 4-inch balls are used, weighing approximately 8 pounds each, and they are cast at a local foundry for $55 a ton f.o.b. Helena. The consumption of these balls amounts to 1.30 pounds per ton of new ore ground. The ball-mill liners are made of white cast iron, but figures on the consumption of liner material are not yet available. Table 2 gives screen analyses of ball-mill and classifier products.

Table 2.--Screen sizes of ball-mill and classifier products

Screen size	Ball mills		Classifiers	
	Feed, per cent	Discharge, per cent	Sand, per cent	Overflow, per cent
On 9/16 by 1 inch	6.70	----	----	----
On 4 mesh	49.21	----	----	----
On 8 mesh	----	1.69	2.42	----
On 20 mesh	26.63	2.11	2.57	----
On 80 mesh	10.55	52.44	58.38	3.85
On 100 mesh	1.32	18.51	20.99	7.69
On 150 mesh	1/5.59	6.85	7.71	11.67
On 200 mesh	----	8.45	3.48	17.40
Through 200 mesh	----	9.92	4.40	59.37
Total	100.00	99.97	99.95	99.98

1/ Minus 100-mesh size.

Flotation

The flotation feed as it overflows the Dorr classifiers contains 23 per cent of solids, by weight, and is diluted in the flotation cells to approximately 19 per cent solids by the addition of fresh water. The flotation feed flows by gravity to a splitting box from which two Minerals Separation flotation machines are fed, two-thirds of the material going to a 10-cell 24-inch machine and one-third to a 12-cell 18-inch machine. In each machine the feed enters the bottom of No. 3 cell which is the No. 1 rougher cell, and each rougher cell overflows a froth which flows to No. 1 cell of the machine (see fig. 2). The No. 1 and No. 2 cells of each machine are cleaner cells, and their tailings are returned to the rougher cells. The cleaner cell froths are finished concentrates, which go to an elevator and are lifted to a thickening tank, the underflow of the thickener feeding a 4-foot 2-disk American filter, and the overflow of the thickener being returned to the flotation cells. Each machine makes a tailings product which is pumped to a 35 by 10 foot Dorr thickener, and as much water as is needed is reclaimed, the underflow from the thickener going to the tailings dam.

The ratio of concentration obtained amounts to 1 ton of concentrates to 12 tons of mill feed. An average analysis of the concentrates follows:

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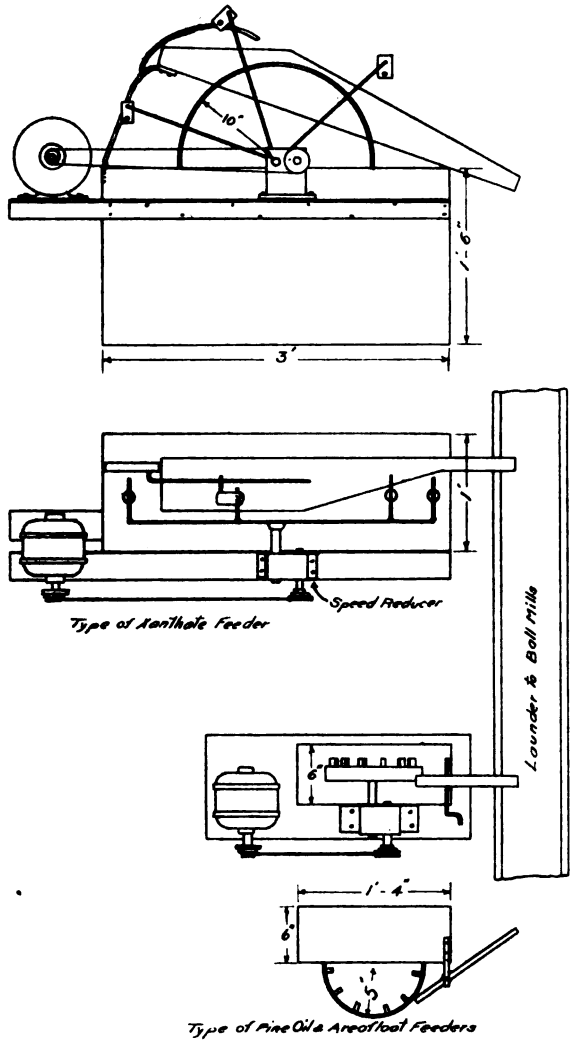

Figure 4.- Flotation-reagent feeders

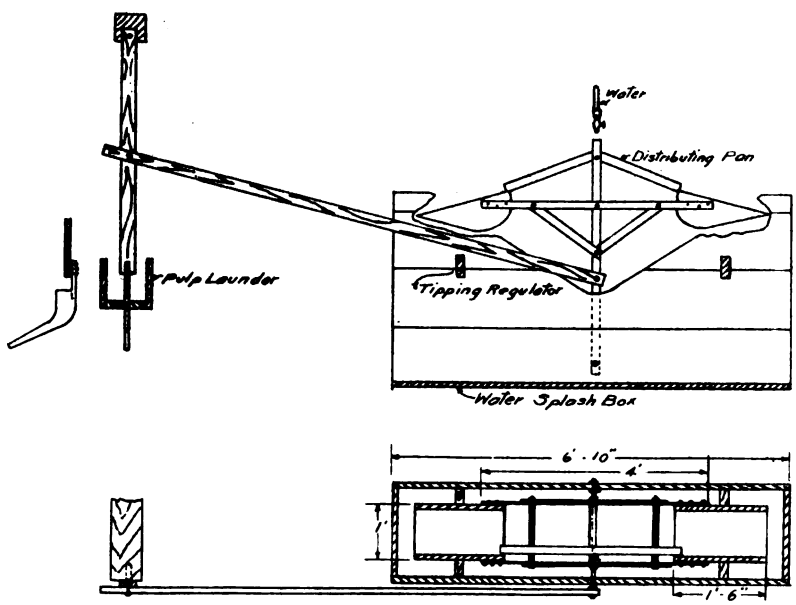

Figure 5.- Samplers

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Analysis of concentrates

Ounces per ton		Per cent				
Gold	Silver	Insoluble	Iron	Arsenic	Antimony	Bismuth
3.24	0.47	9.48	45.44	2.66	0.05	0.223

The flotation reagents are introduced into the grinding mills by the feeders shown in Figure 4. The kinds and amounts of reagents used per ton of ore treated are as follows:

	Pounds
No. 5 pine oil	0.075
Potassium ethyl xanthate	.109
Aerofloat reagent No. 25	.103

Copper sulphate is added, dissolved in circuit water, at the rate of 0.088 pounds per ton of ore ground. The copper sulphate apparently does not aid much in the recovery of gold; however, it makes cleaner and more granular concentrates with an insoluble content 1.5 to 2.0 per cent lower and gives a much better control of froth in the flotation cells.

Two No. 1/4 Roots blowers furnish air to the flotation cells at the rate of 750 cubic feet of free air per ton of ore treated, at 1.5 pounds pressure.

The concentrates are dewatered, as previously mentioned, by a 4-foot 2-disk American filter equipped with palma twill canvas coverings. The filter operates 24 hours per day on a pulp containing approximately 40 per cent of solids, the pulp consistency being maintained by a 1-inch Dorrco diaphram pump between the settling tank and the filter. The filter dewaters concentrates to 9.5 per cent moisture content at the rate of 3.3 pounds of concentrates per square foot of filter area per revolution. The vacuum maintained amounts to between 22 and 23 inches of mercury and the air pressure for blowing the cake from the canvas is maintained at 1.5 pounds. When squeezed by hand, the filter cake has a gritty feeling and crumbles readily.

Table 3 gives a screen-assay analysis of the concentrator heads, and Table 4 a screen-assay analysis of the concentrator tailings. These tables give the assays of gold and iron and the percentages of the total gold and iron for each screen size.

Table 3.--Screen-assay analysis of concentrator heads

Screen size, mesh	Weight, per cent	Assays		Per cent of total metal	
		Gold, ounce per ton	Iron, per cent	Gold	Iron
On 80	3.77	0.280	5.95	3.23	2.96
On 100	6.70	.217	4.60	4.53	4.36
On 150	9.97	.207	5.20	6.35	7.46
On 200	18.83	.275	6.75	16.19	17.99
Through 200.	60.62	.385	7.80	69.68	67.21
Composite ..	99.89	.329	6.92	99.98	99.98

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Table 4.--Screen-assay analysis of concentrator tailings

Screen size, mesh	Weight, per cent	Assays		Per cent of total metal	
		Gold, ounce per ton	Iron, per cent	Gold	Iron
On 80	3.90	0.103	3.26	8.25	3.30
On 100	8.68	.070	3.00	13.14	7.11
On 150	13.33	.060	3.26	15.09	13.52
On 200	15.97	.045	3.40	16.03	14.93
Through 200.	58.12	.038	3.83	47.23	61.14
Composite...	100.00	.047	3.59	99.74	100.00

Disposal of Tailings

The tailings are conveyed in a launder for a distance of 500 feet from the concentrator and impounded in a small ravine. Figure 6 shows a sketch of the tailings dam, including the distributing and decanting launders. The impounding dams are started by laying two rows of logs, tied together by cross logs, across the bottom of the ravine and building the log structure up to a height of three or four logs. The distributing launder is then built across the ravine, above the inner row of logs, the launder bottom having 1-inch holes bored on 2-foot centers. Small mounds of sand form where the water and sand drop through the 1-inch holes. The sand is then shoveled against the outer row of logs, and in this manner a sand and log face is maintained higher than the general level of the pond. When the sand level reaches the top of the two rows of starting logs only the outer row of logs is carried higher as the sand pile builds. The logs of this outer row are tied into the sand pile by means of cross poles, small trees with the top branches left on, spiked to the log row and extending for a distance of about 20 feet into the dam.

A decanting launder is carried from the face of the dam up the bottom of the ravine. Floating of the launder is prevented by spiking it to long stakes driven into the ground and piling large rocks on the covered part. The launder is covered with cross planks as fast as needed for the decantation of clear water. The maximum amount of sand and slime going to the pond every 24 hours amounts to 195 tons. The tailings pulp contains 45 per cent of solids, all of which will pass through a 65-mesh screen.

SAMPLING

The heads sampler is set to cut the stream of flotation feed just after leaving the Dorr classifiers, and the tailings sampler is set to cut the stream just before going out of the mill building. The samplers are water-overbalancing cutters, as illustrated in Figure 5. When clean water is available this type of sampler is very positive and can be made in the mill very cheaply. The concentrates are sampled by hand just before entering the filters.

WATER SUPPLY

Water for concentrator operations is obtained from a small stream running in the gulch and is pumped from this creek to a storage tank above the concentrator by a 5 by 8 inch Gould triplex pump. From August until April of each year the creek does not have sufficient water for milling operations and

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during this period approximately 20 per cent of the water used is reclaimed from concentrator tailings water. The water does not contain impurities detrimental to milling operations. The total new water consumption per ton of ore treated averages 104 gallons. The only costs charged against water supply are power and the few necessary repairs and replacements. The power cost is about $0.01 per ton of ore concentrated, and the repair cost is about an equal amount.

PLANT RECOVERY AND METALLURGICAL DATA

The concentrator recovery of gold ranges from 80 to 87 per cent. The assay-screen analysis of concentrator tailings as shown in Table 4 indicates that finer grinding would yield higher recoveries of gold. Laboratory flotation tests on finer ground feed did not, however, improve the recovery sufficiently to warrant the increased expense of finer grinding in the mill circuit.

Table 5 gives metallurgical data averaged for the period July 1, 1929, to March 31, 1930.

Table 5.--Metallurgical data for period July 1, 1929, to March 31, 1930

Heads assay	$ 6.46
Tailings assay	$ 1.22
Total ore concentrated, tons	40,930
Days operated	270
Operating time per day, hours	24
Operating time, per cent	98
Average ore concentrated per 24 hours, tons	153
Recovery of gold, per cent	82
Concentration ratio	12 to 1
New water consumption per ton or ore concentrated, gallons	104
Ball consumption per ton of ore concentrated, pounds	1.30
Reagent consumption pounds per ton of ore concentrated:	
Pine oil	0.075
Potassium ethyl xanthate	0.109
Aerofloat	0.103

SUMMARY OF COSTS

Table 6 gives a summary of concentrator and crushing plant costs averaged for the period July 1, 1929, to March 31, 1930, and Table 7 gives concentrator and crushing-plant costs segregated and averaged for the same period.

Four men are employed in the crushing plant as operators and six men in the concentrator as operators. The other employees are one mechanic, one electrician, one carpenter, and one man on the tailings dam.

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Table 6.--Summary of concentrator and crushing-plant costs

Period covered: July 1, 1929, to March 31, 1930. Ore concentrated, tons: 40,930
Gold produced, ounces: 10,723.6

	Dollars per ton of ore concentrated					
	Labor	Supervision	Supplies	Reagents	Power	Total
Crushing and conveying	0.062	0.001	0.050		0.049	0.162
Grinding	.100	.001	.072		.117	.290
Flotation	.108	.001	.055	0.063	.031	.258
Disposal of tailings	.048	.001	.003			.052
Water		.001	.001		.010	.012
Repairs and maintenance	.102	.001	.130			.233
Total	0.420	0.006	0.311	0.063	0.207	1.007

Table 7.--Concentrator and crushing-plant costs segregated for period July 1, 1929, to March 31, 1930

	Dollars per ton of ore concentrated					Per cent of total cost
	Labor	Supplies	Repairs	Power	Total	
Crushing and conveying	0.063	0.050	0.060	0.049	0.222	22.0
Concentrating	.363	.194	.070	.158	.785	78.0
Total	.426	.244	.130	.207	1.007	100.0
Per cent of total cost	42.3	24.2	12.9	20.6	100.00	

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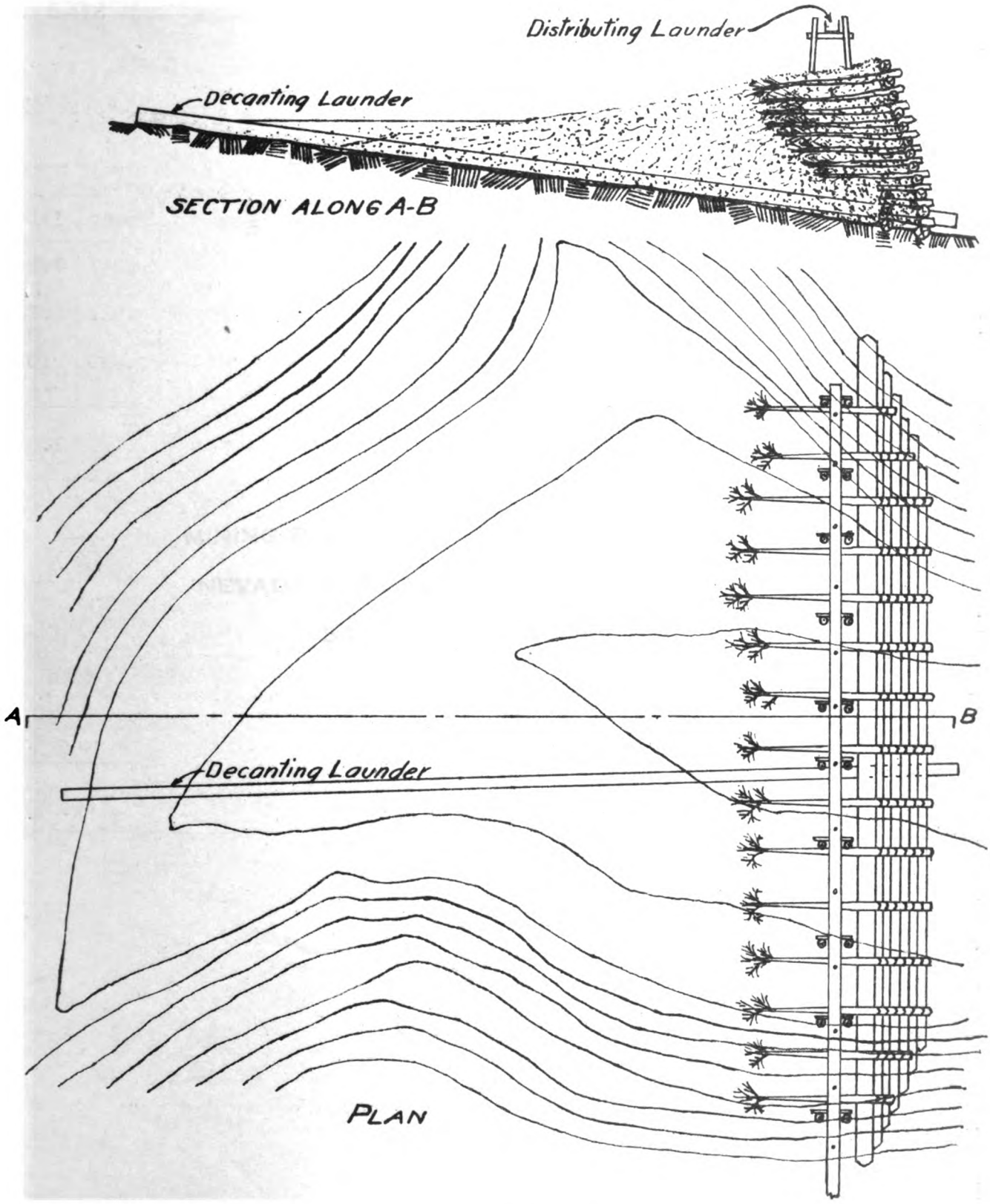

Figure 6.- Tailings dam

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